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SPECIAL ARTICLES

A FURTHER STATISTICAL STUDY OF AMERICAN MEN OF SCIENCE

II

In addition to the 269 men added to the thousand, whose origin, education, distribution, ages and standing have been considered, there were 731 men on the list of 1903 who retained places on the list of 1910. Some of them maintained about the same places as before, some improved their positions and some dropped down to lower places on the list. The number of places that each individual moved up or down is known. A gain or loss of a hundred places at the bottom of the list would not be significant, as the probable error of the change would be about $100 \times \sqrt{2}$. A gain of a hundred places at the top of the list, where the probable error is under twenty places, would represent a certain and important advance in the estimation in which the work of the individual is held. The value of gains or losses in different points in the series is inversely as the probable error corrected by the range, and it is thus possible to represent the gains or losses of individuals wherever they occur in comparable figures. If a gain of one place in the last five hundred is taken as the unit, a gain of one place in the upper hundreds would be approximately as follows: V. = 1.5; IV. = 2; III. = 3; II. = 6, and I. = 10. Dividing further the first hundred, a gain in the lower fifty equals 8, and gains in the two upper twenty-fives, respectively, equal 10 and 14. On such a scale the gain or loss of each individual has been assigned. It is a truly dramatic figure expressing with almost brutal conciseness the efforts, the successes and the failures of seven years of a man's life.

The gains and losses of those on the list of 1903, apart from the 68 who died or removed from the country, are shown in the accompanying curve (Fig. 1).

It is a tolerably symmetric surface of distribution, in view of the limited number of cases and the complicated conditions. 357 men improved their positions and 575 lost ground, of which latter 201 dropped out of the thousand. The average loss was 113 places, these being places in the lower five hundred, equal to one tenth as many places in the first hundred. Apart from this average change in one direction, or constant error, there was an average change of position, or variable error, which referred to the age groups in 305 places.

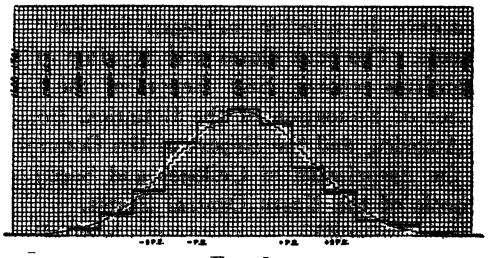

Fig. 1.

This variable error is due to two factors—the chance error of arrangement (say 141) and the real change in the position of the men—and is equal to the square root of the sum of their squares. The real variable error is consequently 270. Men on the list thus lost on the average 113 places, and from this average there was a loss or gain of position, which on the average amounted to 270 places.

The removals from the list would tend to give higher positions to those remaining on it. If the 68 removals were equally distributed over the list, they would allow on the average an advance of 34 places to each man, or, weighting the places, an advance of 73 places of the value of those in the lower five hundred. Instead of such an advance, there was an average loss of 113 places and consequently a total average loss of 186 places. With a gross variable error of 305 places there might be expected to be dropped from the list about 155 men, apart from any negative constant error or any positive advance due to the deaths.

In a stationary scientific population it might be reasonable to assume that the losses by death would be filled by those below the thousand and that those in the thousand would maintain the same or an improved average

position, while only so many would be dropped from the thousand as are accounted for by the variable error. In an increasing scientific population, however, the standard of the thousand would become higher. If there were an increase of ten per cent. in the number of scientific men in the course of seven years, then there should be 110 of the same rank as the first hundred in the thousand of 1903 and 1,100 of the same rank as the thousand. A man in the lower part of the list who maintained his absolute position would lose nearly a hundred places in relative position, and, apart from the variable error of position, 91 of those in the thousand would drop to the eleventh hundred. As a matter of fact the average loss in position was 113 places, and the number dropped from the list was 46 in excess of those accounted for by the variable error. According to this argument, the increase in the number of scientific men of standing in seven years would be from 5 to 11 per cent., or about one half the increase of the population. There has certainly been no increase in the number of scientific men of standing commensurate with the increase in the instructors, students and endowments of our universities, with the larger appropriations for scientific work under the government, or with the new foundations for research.

Table V. gives the gains and losses of the thousand scientific men of the list of 1903 (apart from the 68 who died or removed from the country) in reference to their standing and their present ages. It thus appears that in each hundred of the thousand the men were more likely to lose in position than to gain, but that those in the first hundred lost the least and those in the upper hundreds lost less than the average. Of those in the first hundred 44 gained in position and 46 lost, the average loss being 53 places. They were not subject to the competition of an increasing population, and only seven men not on the list of 1903 attained places among the second hundred. It thus appears that even men of established reputation do not maintain their positions, they do not advance as they grow older, and death removes more eminent men whose places they might fill. The losses tend to increase as the men are of lower rank, but the differences are not considerable. The variable error being 305 places, the probable error of the figures given in the table is rather large.

In the case of age it is clear that the younger men in the thousand are likely to improve their positions, while the older men are likely to fall back. The nine men now under thirty-five have, on the average, gained 364 places and the 77 now between thirty-five and thirty-nine have, on the average, gained 144 places. Of those under forty, 54 gained and 32 lost. In the next five-year period men are about as likely to lose as to gain, whereas older men are likely to lose. There appears to be a plateau between the ages of those now between fifty-five and seventy-four; in the

TABLE V. GAINS AND LOSSES IN REFERENCE TO POSITION AND TO AGE

Position.	1-100.	101-200.	201-300.	301-400.	401-500.	501-600.	601-700.	701-800.	801-900.	901-1000		Totl.
Number	90	91	95	92	91	92	97	93	94	97	—	932
No. gained	44	40	37	34	35	28	40	31	26	42	—	357
No. lost	46	51	58	58	56	64	57	62	68	55	—	575
Constant error	−53.3	−93.9	−99.4	−64.5	−115.8	−160.8	−95.3	−165.0	−182.9	−89.1		
Age.	30-34.	35-39.	40-44.	45-49.	50-54.	55-59.	60-64.	65-69.	70-74.	75-85.	Not Kn'n.	Total.
Total number	9	77	187	194	155	104	85	52	38	24	7	932
No. gained	6	48	94	79	60	23	17	14	11	1	4	357
No. lost	3	29	93	115	95	81	68	38	27	23	3	575
Constant error	+364	+144	+29	−103	−134	−276	−268	−262	−227	−438		
Variable error	*485*	*328*	*366*	*284*	*308*	*285*	*252*	*299*	*258*	*185*		

course of the seven preceding years they have about the same record. They tend to lose about 250 places or about twice the average of all the men on the list. The 24 men who seven years ago were sixty-eight years of age or older have nearly all lost in position. It is not likely that any one of them has done anything to lower his scientific reputation; but men of the younger generation have accomplished work of greater importance, or the work of older men is forgotten because it is less contemporary. It thus appears that under existing conditions in this country, scientific men are likely in the course of seven years to lose about 100 places. Men who have obtained recognition among the thousand are likely to gain if under forty; if between forty and fifty they are likely to lose, and if over fifty-five they are likely to lose more than the average.[5a]

The average age of the thousand scientific men on the list of 1910 is 48.12 years. The age distribution is as follows:

Age	Number
25–29	6
30–34	54
35–39	155
40–44	214
45–49	176
50–54	137
55–59	82
60–64	68
65–69	40
70–74	33
75–79	13
80–84	7
Unknown	15

In Table VI. is given the average age of the men in the ten groups of one hundred making up the thousand for the lists of 1903 and 1910.[6] The probable errors of the averages are less than one year. It thus appears that the more eminent scientific men are likely to be older; but the differences are small apart from the first hundred, who in 1903 were 5.1 years older than the average, and in 1910 6.7 years older. Scientific men do not become more eminent as they grow older unless they have obtained a good position at a comparatively early age.

The men on the list of 1910 are, on the average, three years older than those on the list of 1903. An increase in age would be

[5a] The coefficient of correlation between age and gain in position is — 31.7. It is, however, doubtful whether the Galton-Pearson method can be used to advantage in such cases.

[6] The list for 1903 used for ages consisted of the 1,000 scientific men who stood first before the adjustments had been made to secure a fixed number in each science.

TABLE VI. AVERAGE AGE ACCORDING TO POSITION IN 1903 AND 1910

	Average Age.			Average Age.	
	1903.	1910.		1903.	1910.
I.	50.12	54.78	VI.	43.70	46.40
II.	49.76	48.94	VII.	41.97	45.60
III.	47.04	48.34	VIII.	42.36	47.82
IV.	45.38	48.62	IX.	43.50	45.94
V.	44.09	48.50	X.	42.32	46.14
			Average	45.02	48.11

TABLE VII. AGES AT WHICH THE BACHELOR'S DEGREE AND THE DOCTORATE OF PHILOSOPHY WERE RECEIVED ACCORDING TO SCIENCE AND TO POSITION IN THE THOUSAND

	Bachelor.		Ph. D.	
	No.	Age.	No.	Age.
Mathematics	67	21.9	64	28.4
Physics	112	22.1	87	28.6
Chemistry	132	21.6	114	26.7
Astronomy	34	21.6	14	29.3
Geology	85	22.8	43	28.5
Botany	83	23.7	56	30.5
Zoology	117	22.6	96	28.8
Physiology	29	21.7	19	26.7
Anatomy	15	23.7	2	30.5
Pathology	30	20.7	6	27.2
Anthropology	8	22.0	6	27.5
Psychology	46	21.7	37	27.6
No. or average	758	22.2	544	28.4
I.	74	21.6	57	26.9
II.	77	21.9	52	27.3
III.	80	22.3	56	27.7
IV.	74	22.2	52	27.5
V.	74	22.2	53	28.2
VI.	74	22.0	63	29.3
VII.	79	22.4	52	28.6
VIII.	76	22.2	58	28.8
IX.	74	22.8	49	29.3
X.	76	22.8	52	29.1
No. or average	758	22.2	544	28.4

expected, as we have to do with a youthful and increasing scientific population. Some part of the increase in age is probably caused by the long period of education now likely to precede productive scientific work, but it is not easy to analyze the factors. In so far as the increased age is due to higher standards through increasing competition, it is gratifying; in so far as it is due to the postponement of scientific productivity, it is unfortunate.

For the list of 1903 data have been compiled in regard to the ages at which academic degrees were received. The average age at which 758 men received the bachelor's degree was 22.2 years, and the average age at which 544 men received the doctorate of philosophy or science was 28.4 years. The corresponding median ages were 21.8 and 26.9 years. Table VII. shows the details in reference to the different sciences and the ten groups of a hundred composing the thousand. The age differences are small, but men have received the bachelor's degree at an earlier age who have become pathologists than those who have become anatomists or botanists. The chemists have received the doctor's degree at the earliest age and the anatomists and botanists at the latest. The mathematicians have received the doctorate at exactly the average age, not earlier, as the writer would have anticipated.

In the different sciences there are decided differences in the proportion of those who have received academic degrees. Only half the pathologists have the bachelor's degree and one twelfth the doctorate of philosophy, their education having been in the medical school. Of 50 psychologists 46 hold the bachelor's and 37 the doctor's degree. The doctor's degree is held by nearly two thirds of the zoologists, while it is held by less than half the geologists and less than a third of the astronomers.

There is a small but definite correlation between standing and the age at which the men received their degrees—the more eminent the men the earlier the age. Those in the first hundred have received both the bachelor's and the doctor's degree at the earliest age, the former 0.6 and the latter 1.5 years below the average. The second hundred are the next youngest, the ages for the two degrees being 0.3 and 1.1 below the average. Those in the lower two hundred were 0.6 year older than the average in receiving the first degree and 0.8 year older in the case of the second degree. There is no correlation between standing and the possession of one or the other of the degrees.

Our thousand leading men of science are occupied as shown in Table VIII. 738.5[7] are engaged in teaching, or have been so engaged, and now fill administrative educational positions or have retired from active service. Nearly three quarters of our scientific men earn their livings by teaching, and a large proportion of the others have done so. In this country, as in Germany, the advancement of science depends mainly on those who hold chairs in our colleges and universities. Some ten per cent. of our scientific men are engaged in work for the government, among whom the geologists predominate. Only six per cent. earn their livings by direct applications of science. Apart from one actuary, this work is in applied chemistry, engineering and mining. There is no one who earns his living by applications of the natural sciences. Research institutions, nearly all of recent foundation, employ 35 men. There are 24 connected with museums, academies and libraries and 12 with botanical gardens. Only eleven among the thousand may be classed as amateurs, and these include several married women who should perhaps be given a separate place. This contrasts with Great Britain, where Darwin, Huggins, Rayleigh and many other great scientific men, not needing to earn their livings, have devoted their lives to scientific research. Only three physicians not connected with medical schools have done scientific work of consequence. One architect, one artist, one editor and one missionary appear on the list, but no lawyer or man of business. It seems that in this country the time has gone by when science can be advanced by any except by those engaged in certain definite profes-

[7] The decimal here and elsewhere refers to a man who gives part of his time to teaching or to the institution to which he is credited.

TABLE VIII. OCCUPATION OF THE THOUSAND MEN OF SCIENCE ACCORDING TO SCIENCE AND TO POSITION

	Teaching.	Government Work.	Applied Science.	Research Institutions.	Museums and Academies.	Botanical and Zoological Gardens.	Amateurs.	State Work.	Physicians.	Architects.	Artists.	Editors.	Missionaries.	
Mathematics	77	1	1									1		80
Physics	104	18	22	6										150
Chemistry	126.5	12	28	8.5										175
Astronomy	38	5		4			3							50
Geology	52.5	30.5	8	1	2		1	5						100
Botany	66	12		6	2.5	12.5	1							100
Zoology	112.5	14		3	15.5	1	2				1		1	150
Physiology	37	1		2										40
Anatomy	21			2	1		1							25
Pathology	51	4		3					2					60
Anthropology	7.5	8			3.5		1							20
Psychology	45.5	0.5					2		1	1				50
	738.5	106	59	35.5	24.5	13.5	11	5	3	1	1	1	1	1000
1– 100	79	7	1	6	3	2	2	?	?	?	?	?	?	100
101– 200	78	12	2	4	1		1							100
201– 300	80.5	12	3	2	1.5									100
301– 400	67	18	8	1	2	3								100
401– 500	69	11	5	4	4	2	1							100
501– 600	78	9	7		2	3								100
601– 700	67.5	11	5	8	3	2.5	2							100
701– 800	72	12	9	3	3									100
801– 900	69.5	6	11	4.5	3	1	4							100
901–1000	78	8	8	3	2		1							100
	738.5	106	59	35.5	24.5	13.5	11							1000

sions, while these professions require men, with a few exceptions, to earn their livings by teaching or by applied science.

The standing of those in the different professions does not show a considerable difference. There are in the upper three hundred relatively more men engaged in teaching and in the research institutions, and fewer in applied science, but the differences are scarcely significant, except that those engaged in applied science are of somewhat lower standing. Those in the government service and the officers and curators of museums and botanical gardens are of average standing.

There were 19 women on the list of 1903. None of them died but seven were not placed on the list of 1910. This is a somewhat larger proportion than in the case of the men, but the figures are too small to have significance. Six women found a place for the first time on the list of 1910, the highest being in the fifth hundred. It thus appears that women have not improved their position in science in the course of seven years, and it is not an important one, only 18 women among 982 men, with none in the first hundred, two in the second, two in the third and three in the fourth. There are now nearly as many women as men who receive a college degree; they have on the average more leisure; there are four times as many women as men engaged in teaching. There does not appear to be any social prejudice against women engaging in scientific work, and it is difficult to avoid the conclusion that there is an innate sexual disqualification. Women seem not to have done appreciably better in this country than in other countries and periods in which their failure might be attributed to lack of opportunity. But it is possible that the lack of encouragement and sympathy is greater than appears on the surface, and that in the future women may be able to do their share for the advancement of science.

TABLE IX. DISTRIBUTION OF THE FIRST AND SECOND THOUSANDS

	First Thousand.			Second Thousand.	
	No.	Gain or Loss.	Per Million 1900.	No.	Per Million 1900.
North Atlantic.					
Maine	3	− 1	14.3	5	7.2
New Hampshire	8	0	19.4	8	19.4
Vermont	1	− 1	2.9	6	17.4
Massachusetts	165	+21	58.7	103	36.7
Rhode Island	9	+ 1	20.9	11	25.7
Connecticut	50	+ 7	55.0	32	35.2
New York	183	− 9	25 1	166	22.8
New Jersey	26	− 9	13.2	29	15.3
Pennsylvania	60	− 5	9.5	69	10.9
South Atlantic.					
Delaware	0	− 1	0	4	21.7
Maryland	39	− 8	32.8	30	25.2
Dist. of Columbia	109	−10	391.0	111	399.2
Virginia	10	0	5.4	14	7.5
West Virginia	2	− 1	2.0	3	3.1
North Carolina	7	+ 1	3.7	7	3.7
South Carolina	0	0	0	3	2.2
Georgia	0	− 1	0	1	0.4
Florida	0	0	0	3	5.7
South Central.					
Kentucky	0	− 3	0	5	2.3
Tennessee	1	− 2	0.5	8	3.9
Alabama	2	0	1.1	2	1.1
Mississippi	0	0	0	1	0.7
Louisiana	4	+ 3	2.9	1	0.7
Texas	4	− 3	1.3	10	3.2
Oklahoma	0	0	0	2	5.0
Arkansas	0	0	0	1	0.7
North Central.					
Ohio	34	0	8.2	39	9.3
Indiana	11	− 1	4.4	21	8.3
Illinois	77	+14	15.9	87	18.0
Michigan	25	− 2	10.3	31	12.8
Wisconsin	36	+13	17.4	14	6.7
Minnesota	13	0	7.4	20	11.4
Iowa	6	− 1	2.7	15	6.7
Missouri	24	+ 3	7.7	19	6.1
North Dakota	1	− 1	3.1	4	12.5
South Dakota	1	− 1	2.4	2	4.9
Kansas	5	0	3.4	14	9.5
Nebraska	6	− 3	5.6	11	10.3
Western.					
Montana	0	− 2	0	3	12.3
Wyoming	0	− 1	0	1	10.9
Colorado	9	+ 1	16.6	13	24.1
New Mexico	0	− 2	0	1	5.1
Arizona	4	+ 2	34.2	2	16.4
Utah	0	0	0	5	18.1
Nevada	0	0	0	1	21.4
Idaho	0	0	0	2	12.4
Washington	0	0	0	6	11.6
Oregon	1	+ 1	2.4	1	2.4
California	50	− 3	33.6	38	25.6
Hawaii	2	+ 2	12.9	1	6.5
Porto Rico	0	0	—	1	—
Panama	1	+ 1	—	0	—
Philippines	4	+ 1	—	8	—
Canada	1	− 1	—	0	—
Mexico	0	0	—	1	—
Cuba	1	0			
Brazil	1	0	—	0	—
Argentine	2	+ 2	—	0	—
Peru	0	0	—	2	—
France	1	+ 1	—	0	—
Germany	0	0	—	1	—
Switzerland	1	+ 1	—	0	—
Turkey	0	0	—	1	—
Number	1000			1000	

Table IX. gives the distribution on January 1, 1910, of the thousand leading scientific men of the country and the gain or loss of each state in a period of about four years. The distribution of the second thousand is also shown. In respect to the first thousand, the main facts have already been considered in connection with the men who have acquired or lost places in the group. This table shows in addition the changes which have occurred as the result of men removing from one state to another who have retained their places on the list. Massachusetts, as has been noted, gained 14 men owing to the fact that 43 of the new men reside in that state, while but 29 were lost to it through death or through dropping below the standard. In addition it has gained seven men, the excess of those having places on both lists who have moved into the state above those who have left it. Its total gain in scientific men of standing is consequently 21, and it has 58.7 of these scientific men per million of its population according to the census of 1900, as compared with 51.3 about four years ago. The increase in the number of scientific men is nearly 13 per cent. This is an honorable record. It is commonly assumed that Boston has yielded to New York City the position of literary center of the country, and if the facts were not known the same assumption would probably be

made in regard to science. As a matter of fact Boston has 126, New York 120 and Washington 110 of our leading scientific men. In comparison with population and with wealth, Boston is far in advance of New York, though it is Cambridge and Harvard University which give Boston its preeminent position.

New York and Pennsylvania have in part retrieved the loss due to men dropping out of the first thousand by calling men of this rank from other states. Though they have lost, respectively, 22 and 12 through the failure of their men to maintain their positions, they have drawn an excess of 13 and 7 from other states, so that their total losses are 9 and 5. It appears that the immense wealth of these states has been but sparingly used to bring new men to them, whereas the conditions are such that those residing there are more likely to lose than to gain in scientific position. It may be unsafe to draw sweeping conclusions from such figures, but they certainly indicate that residence in these states is unfavorable to scientific productivity. It may perhaps be the case that the salaries are below the expensive standards of living and that opportunities for commercial and hack work are tempting, so that men are drawn away from research. The District of Columbia has lost nine men. Eleven have been removed by death, and this loss has not been made good by men improving their positions or going to reside in Washington. In view of the increasing appropriations made by the government for scientific work and the endowment of the Carnegie Institution this is not a favorable record.

Illinois and Wisconsin show the gains due to men who have improved their positions, there being no significant changes due to removals. The same is generally true in regard to the gains or losses in the other north central states and in the west and south. The numbers are too small to be as a rule significant. Missouri and Louisiana have each gained three men, Arizona two and Colorado one. Ohio and Minnesota are exactly stationary. Indiana, Michigan, Iowa, Texas and California have in each case lost from one to three men. The southern states (except Louisiana) have been losing even the few scientific men whom they had.

Table IX. shows also the distribution of the thousand scientific men standing below the first thousand. The men are not as well known and they can not be arranged as accurately in the order of merit. They were not independently selected from a larger group by the judges, but were those not assigned a place in the first thousand. The first five hundred were selected from the thousand with a tolerable degree of validity, but the second five hundred can only be regarded as representative of the scientific men who have done research work, but are not of the rank of the first fifteen hundred. The men are, however, arranged in the order of merit, and probable errors can be assigned to the positions as in the case of the first thousand. The number from each science is the same as in the case of the first thousand.

It is an honor to belong to this second group of a thousand men; they deserve well who have accomplished research work and have obtained recognition as scientific men. But those who are young have far greater promise than those who are older. All young men of ability must pass through the second thousand before they reach the first, though they are likely to escape notice in a period which may be short. The group is thus heterogenous, including those who may become our leading men of science and those who have attained a mediocre though creditable position beyond which they will not advance. The same conditions hold for the lower hundreds of the first thousand. In the preceding paper the scientific men were divided into two groups of 500 each, and no considerable differences were found in their origin or distribution. This appears to have been in part due to heterogeneous character of the second group. Thus Massachusetts had 74 men in the first five hundred and 70 in the second, while New York had in the two groups 93 and 99, respectively. But in the intervening period more men in Massachusetts than in New York have retained or improved their positions. It

thus appears that Dr. F. A. Woods[8] is correct in holding that Massachusetts has not only produced more scientific men, but also men of higher standing.

The second thousand includes those who have dropped down from the first thousand (201), to whom consideration has already been given. The others have been divided into those above and those below the median age (42 years), but the conditions are almost too complicated to admit of analysis, and it seems to be scarcely worthwhile to give the figures. In New York 43 are below and 68 above the median age; in Illinois 37 below and 28 above, and in California 9 below and 18 above. The excess of older men in New York may be attributed to its earlier development and to the fact that older men, especially in applied science, tend to reside in New York City. Chicago is of more recent origin and has called younger men to its universities. In Massachusetts and the District of Columbia there are about equal numbers below and above the median age. Older men reside in Boston and Washington, and younger men have been called to the institutions of learning in the former city and to the government service in the latter. The eight scientific men in the Philippines are all below the median age.

The men of the second thousand are more equally and widely distributed over the country than those of the first thousand. The regions and institutions which are the strongest in numbers tend to have also the larger share of men of the higher rank. Thus Massachusetts has 165 men of the first thousand and 103 men of the second thousand; Connecticut 50 of the first and 32 of the second. The educational institutions of these states have called and kept good men. They have relatively more in the first thousand than in the second, as they have relatively more in the first hundred than of lower rank. New York has a smaller preponderance of the better men. In the District of Columbia the scientific men are drawn equally from the first and second thousands. Thanks to the recent development of its great university, Wisconsin has 36 men in the first thousand and 14 in the second. The superior men are in the majority in Missouri, but the other north central states have fewer men of the first rank than of the second. California has 50 men of the first thousand and 38 of the second. In general the western and southern states which have but few scientific men have relatively more of the second thousand. It is of course important to have even men of this rank. There are advantages and disadvantages in concentrating the better men in a few regions and institutions. The standards of the men in both thousands are becoming higher, though more slowly than would be wished.

The distribution of our scientific men is almost entirely determined by educational and scientific institutions, including under the latter the government bureaus. Table X. shows the institutions with which three or more of those among our thousand leading men of science are connected, together with the gain or loss in a period of about four years. The table also gives the ratio of the number of leading scientific men in each institution to the total number of instructors, to the total number of students, to the value of buildings and grounds and to the current income. Harvard, Wisconsin, the Carnegie Institution, Illinois, Yale and Chicago have made the most notable gains. Columbia, California, the Geological Survey, the Smithsonian Institution and the Department of Agriculture have suffered the most severe losses. Four years ago Harvard had 66.5, Columbia 60 and Chicago 37 of our leading scientific men, as selected three years previously. After this short period it has resulted that Harvard has 31.5 more than Columbia and Chicago the same number. Such changes are only to a small degree due to the probable errors of the arrangements, though in the case of Columbia the fact that last time there were 11 and this time but two men in the last hundred may be attributed in part to the probable error and account in part for the loss of that university. There is also a different kind of chance variation due to the

[8] "American Men of Science and the Question of Heredity," SCIENCE, N. S., **31**: 205–209, 1910.

date to which the census refers. Thus since January 1, Harvard has lost two of its greatest men, while the losses of Columbia occurred earlier and certain important positions were vacant at that time. It is, however, a fact not without significance that Columbia and California, in which faculty control is regarded by the administration as less important than executive efficiency, have suffered the most serious losses, whereas Harvard and Yale, where the methods of appointment and promotion are more democratic, show most gratifying advances. Yale has disproved the assertion that a faculty is not able to select its own members. The Smithsonian Institution and the government bureaus, which are somewhat autocratically controlled, show serious losses, but these should be in part at least attributed to the inadequate salaries. The gain of 50 per cent. in the Bureau of Standards shows that losses are not inevitable.

Wisconsin and Illinois are the state universities which have made the most notable progress. Wisconsin has moved ahead of Michigan and is nearly equal to the Johns Hopkins and Cornell. The gain of almost 200 per cent. at Illinois is in the main due to the departments of chemistry and mathematics, to the heads of which the university was so wise as to call men of high scientific standing. Michigan has a gain of 3.5, Missouri of two and Indiana of one. Minnesota and Kansas are exactly stationary. Ohio has a loss of one, Iowa and Texas of two and California of 8.5.

The Johns Hopkins has gained three men, which is satisfactory in view of its limited endowment and the high standards it has always maintained. The Massachusetts Institute of Technology has gained 5.5, Cornell 1.5, Pennsylvania 1, Princeton 2 and Stanford 5. We may hope for a considerable further advance at Princeton in the near future. It will be noted that in general the larger institutions have gained, and this relative gain represents a greater absolute gain as the standard of the thousand becomes continually higher with the increase of the numbers of scientific men.

Among universities with which fewer scientific men are connected, Western Reserve has gained four men and Brown, Missouri and Tulane have each gained 2, whereas Nebraska has lost 3 and Wesleyan, Syracuse, Northwestern, Cincinnati and Texas have each lost two. Bryn Mawr, Vassar and Wellesley have gained and Smith has lost. Small changes of this character are not necessarily significant, as they may be accounted for by the chance error of arrangement or the chance date to which the data refer. Still in each case the change is probably a real one and of importance when considered in relation to the total number of professors in the institution. The gain of a scientific man of standing is worth more to an institution than a building costing $100,000.

Table X. gives also the ratio of the number of scientific men of the thousand in each institution to the total number of instructors, to the total number of students, to the value of the buildings and grounds and to the income for current expenses, the figures being based on the report of the commissioner of education for 1909.[9] The institutions vary

[9] Unfortunately the figures in the report do not seem to be uniformly accurate. For example, the value of the buildings of Columbia University are reported by the commissioner of education at $2,238,800, and those of the U. S. Military Academy at $20,000,000, whereas the buildings on the Columbia campus have apparently cost much more than those at West Point. The treasurer gives the assessed value of the Columbia buildings (apart from Barnard College, Teachers College and the College of Pharmacy) as over $6,000,000. The commissioner of education reports the total receipts of Columbia University, exclusive of gifts for endowment, to have been $5,572,943, whereas the treasurer reports for the same year an income for the Columbia College corporation of $1,614,-166. The correct figures have been substituted in the case of Columbia, but it is to be feared that other figures in the report are misleading. The writer considered using the figures collected by the Carnegie Foundation, but these also seem to be difficult to interpret. Thus Illinois is said to have an annual income (for running expenses) of $1,200,000 and to spend $491,675 on salaries of

greatly. One half of all the instructors at Clark are among our leading men of science, whereas in certain institutions there is but one in fifty. The institutions which stand the highest are Clark, the Johns Hopkins, Chicago, Stanford, Bryn Mawr, Harvard, Wesleyan, Case and Princeton. These institutions have at least one scientific man of standing among each ten instructors. It is of interest to note that the five institutions that have the best record are of comparatively recent establishment. They have given a relatively more prominent position to science than the older institutions and have selected better men. At certain other institutions the ratios are: Yale, 10.6; Michigan, 12.3; Wisconsin, 13.2; Columbia, 13.3; Cornell, 16.5; California, 21.3; Pennsylvania, 25.2. The institutions having more than forty instructors to one scientific man of standing are George Washington, Pittsburgh, Tufts, Tulane, Syracuse, Northwestern, Indiana and Cincinnati. These differences are truly remarkable and should be widely known in the interest of scientific education and the advancement of science. Institutions differ in the relative strengths of their departments, but it will be found that those which have men of distinction in the natural and exact sciences also have such men in other subjects. Students should certainly use every effort to attend institutions having large proportions of men of distinction among their instructors. It will be ordinarily the case that in such institutions the younger instructors are also of higher standing. Scientific men, especially those beginning their careers, should try to accept positions only where the higher standards obtain.

In general the institutions which have a large proportion of scientific men of distinction among their instructors will also have a large number in comparison with the student attendance. But institutions vary greatly in the number of students for each instructor—from 3.9 at the Johns Hopkins to 18.1 at

teachers, and Pennsylvania to have an annual income of $589,226, and to spend $433,311 on salaries.

TABLE X. THE NUMBER OF SCIENTIFIC MEN CONNECTED WITH INSTITUTIONS WHEN THERE ARE THREE OR MORE

	No.	Gain or Loss.	Ratio to Instr.	To Students.	To Buildings and Grounds.	To Income.
Harvard	79.5	+13.0	7.8	49.2	138,364	24,729
Chicago	47.5	+ 8.5	6.0	114.9	187,741	35,986
Columbia	48.0	−12.0	13.3	96.7	259,954	45,989
Yale	38.0	+11.5	10.6	90.3	——	34,142
Cornell	35.0	+ 1.5	16.5	113.9	122,966	41,106
Johns Hopkins	33.5	+ 3.0	5.6	21.8	186,095	10,121
Wisconsin	30.0	+12.0	13.2	150.7	126,104	50,499
Dept. Agric.	28 0	− 4.0	—	—	——	——
Geol. Surv.	25.5	− 6.5	—	—	——	——
Mass. Inst.	25.0	+ 5.5	10.1	58.5	53,480	20,859
Michigan	23.5	+ 3.5	12.3	200.8	87,649	57,539
Stanford	21.0	+ 5.0	6.9	80.3	333,810	39,571
Carnegie Inst.	19.0	+12.0	—	—	——	——
California	18.5	− 8.5	21.3	191.9	281,761	81,387
Pennsylvania	18.0	+ 1.0	25.2	229.0	——	56,368
Illinois	17.0	+11.0	29.2	251.9	111,971	99,647
Princeton	16.5	+ 2.0	9.8	79.7	——	24,964
Smithsonian	16.0	− 6.0	—	—	——	——
Bur. of Stan.	12.0	+ 4.0	—	—	——	——
Missouri	11.0	+ 2.0	14.7	259.4	157,591	54,870
Minnesota	10.0	0	20.1	264.9	387,008	133,348
Ohio State	9.0	− 1.0	22.1	281.7	323,889	85,784
New York	8.5	− 1.0	28.1	446.5	435,294	49,062
Amer. Museum.	7.5	− 0.5	—	—	——	——
Clark	8.0	+ 1.0	2.0	17.7	66,562	17,585
West. Reserve	8.0	+ 4.0	24.5	126.3	187,996	30,496
Bryn Mawr	8.0	+ 2.0	7.2	52.5	243,649	37,185
N. Y. Bot. Gar.	8.0	+ 2.0	—	—	——	——
Brown	7.0	+ 2.0	12.9	141.9	257,142	65,813
Indiana	7.0	+ 1.0	43.0	353.0	85,842	50,349
Virginia	7.0	0	10.4	112.0	306,714	36,194
Northwestern	7.0	− 2.0	44.6	319.3	——	134,191
Rockefeller Inst.	6.0	+ 3.0	—	—	——	——
North Carolina	6.0	+ 1.0	15.7	131.0	103,833	27,191
Nebraska	6.0	− 3.0	36.1	544.3	210,225	101,509
Dartmouth	5.5	− 0.5	15.4	224.1	345,454	55,338
Washington (St. Louis)	5.0	+ 1.0	27.4	211.6	——	113,408
Kansas	5.0	0	36.2	442.0	220,000	91,775
Iowa State	5.0	− 1.0	30.6	494.4	328,938	109,620
Syracuse	5.0	− 2.0	46.8	627.2	550.051	148,350
Case	4.0	+ 1.0	8.8	111.3	207,500	12,204
Field Museum	4.0	+ 1.0	—	—	——	——
Tufts	4.0	+ 1.0	54.2	279.5	——	54,501
Vassar	4.0	+ 1.0	25.3	254.5	616,421	145,015
Smith	4.0	− 1.0	29.2	393.0	329,875	90,212
Cincinnati	4.0	− 2.0	42.3	348.5	367,030	68,624
Wesleyan	4.0	− 2.0	8.5	80.5	220,616	25,613
Wistar Inst.	3.0	+ 3.0	—	—	——	——
Tulane	3.0	+ 2.0	52.0	365.6	601,297	54,967
Wellesley	3.0	+ 1.5	35.3	427.3	423,841	127,937
Conn. Sta.	3.0	+ 1.0	—	—	——	——
Pittsburgh	3.0	+ 1.0	61.0	414.3	309,844	122,529
Colorado Coll.	3.0	0	19.0	225.3	362,667	29,166
Gen. Elect. Co.	3.0	0	—	—	——	——
G. Washington	3.0	0	61.6	502.6	111,500	58,437
Worcester	3.0	0	16.7	162.6	——	——
Texas	3.0	− 2.0	28.6	611.0	340,234	110,691
U. S. Navy	3.0	− 4.0	—	—	——	——

Chicago.[10] For each scientific man among the thousand, the numbers of students are: Clark, 18; Johns Hopkins, 22; Harvard, 49; Bryn Mawr, 52; the Massachusetts Institute, 58; Princeton and Stanford, 80; Yale, 90; Columbia, 97. These are the institutions which have at least one scientific instructor of distinction for each hundred students. The institutions not having one such instructor for five hundred students are Syracuse, Texas, Nebraska and George Washington.

There are extraordinary differences or discrepancies in the relation between the value of the buildings and grounds of different institutions and their annual incomes for current expenses as given in the report of the commissioner of education. Some institutions, as Michigan and Illinois, are said to spend nearly as much annually on their educational work as the total value of their buildings and grounds, whereas others, as New York, Stanford and Tulane, are said to spend scarcely more than a tenth as much. Apparently but little reliance is to be placed on such figures. In so far as they are correct the Massachusetts Institute has one scientific man of standing for each fifty-three thousand dollars invested in buildings and grounds. The other institutions having at least one scientific man for each hundred thousand dollars so invested are Clark, Michigan and Indiana. The institutions having but one scientific man of standing for four hundred thousand dollars or more invested in buildings and grounds are Vassar, Tulane, Syracuse, New York and Wellesley. The Johns Hopkins supports one leading scientific man for each ten thousand dollars that it spends. The other institutions which have at least one scientific man for each twenty-five thousand dollars spent annually are Clark, the Massachusetts Institute, Harvard and Princeton. Vassar, Northwestern and Minnesota are the institutions that spend the most in proportion to the number of their scientific men.

Men who stand toward the upper end of the list are of far greater consequence than those toward the bottom. Here too Harvard shows its primacy and in unmistakable terms. Of our hundred leading men of science nineteen are at Harvard, as compared with nine at Chicago and seven at Columbia and the Johns Hopkins.[11] Of the second hundred Harvard has 10.5, Chicago 15, Columbia 6 and the Johns Hopkins 3.

It is not possible to estimate the value of a great scientific man in terms of other men. It may even be argued with plausibility that the progress of science depends exclusively on the few men of genius, while the mass of scientific men erect obstacles, and are only of use as a group which on occasion supplies the great man. But in a comparison of this kind we have in mind men such as Galileo, Newton, Laplace and Darwin. In the list of a thousand living American men of science, those in the lead are not incomparable with the others. As a matter of fact, we undertake to measure them by the salaries we pay. These are obviously imperfectly adjusted to merit, and there are kinds of merit other than scientific distinction. If, however, a university pays its more distinguished professors three times as much as its younger assistant professors, it estimates the one to be worth three times as much as the other. In the case of the salaries and earnings of psychologists, it appears that those in the first hundred of the thousand earn about three times, and those in the second and third hundreds about twice as much as those in the lower half of the list. With numerous individual exceptions —some men of high standing even paying for the privilege of doing scientific work, while some men of medium standing may receive comparatively large salaries[12]—we find that

[10] These remarkable differences are confirmed by the report from the Carnegie Foundation, which gives the ratios as 3.7 and 17.4.

[11] The membership of the National Academy of Sciences corresponds closely with these figures—18 at Harvard, 9 at Chicago, 8 at Columbia and 7 at the Johns Hopkins.

[12] It is scarcely necessary to point out again the failure of our competitive system to reward scientific research, but it may be illustrated by an example. Lord Kelvin made a large fortune by his inventions and engineering advice; he earned a modest salary as professor at Glasgow; he was paid nothing for his great contributions

the salaries increase with distinction and roughly measure it, placing it about three times as high in the upper hundred as in the lower third of the list. It is also the case that the range of merit in the curve of distribution covered by the first hundred is almost exactly equal to the range covered by the second and third hundreds, and each of these is equal to the range covered by the remaining seven hundred.[13] It may not be possible to fix a zero point at which scientific merit begins, but it can plausibly be placed at a point below the first thousand, about equal to the range of merit covered by the other three groups. In this case the merit of those toward the bottom of each of the three groups in the thousand—the first hundred, the second and third hundreds, and the last seven hundred—would be as 3:2:1.

In order, therefore, to sum up in one figure the strength of a university or department, weights have been assigned to the men on this basis—a man in the lower four hundred being the unit, those in the other hundreds were assigned ratings as follows: VII. and VI. = 1.2; V. = 1.4; IV. = 1.6; III. = 1.9; II. = 2.2; and I. = 3. The first hundred were subdivided, the lower fifty being assigned 2.5, and the upper twenty-fives, respectively, 3 and 4. These ratings scarcely measure the real value of the men to society; they are nearly all paid less than they are worth, and the greater the performance of a man the more out of proportion is the payment for his services. They do, however, give with tolerable accuracy the value attached to men in our competitive system. A university can obtain a man of the first rank for from $5,000 to $7,500, or a man in the lower hundreds of the list for from $2,000 to $2,500. It is further the case that a moderate alteration in the weights adopted would not considerably alter the comparative results.

The scientific strength of our strongest institutions rated in the manner described, together with the gain or loss in a period of four years is shown in Table XI. Thus Harvard has a total scientific strength equivalent to 146 men in the lower part of the thousand and has made a gain equivalent to 16.3 such men in the course of about four years. In general the figures in this table correspond with those in the preceding table, but they tell us more. They take account not only of the number of men gained or lost, but also of the rank of these men and of the changes which have taken place through men improving their standing or failing to maintain it.

TABLE XI. THE SCIENTIFIC STRENGTH OF THE LEADING INSTITUTIONS

	Weighted Number.	Gain or Loss.
Harvard	146.0	+16.3
Chicago	94.6	+18.0
Columbia	79.3	−13.3
Hopkins	63.4	+ 4.2
Yale	61.7	+12.2
Cornell	57.6	+ 4.6
Wisconsin	49.0	+22.3
Geol. Survey	43.8	−12.2
Dept. Agric.	40.9	− 4.9
Mass. Inst.	37.7	+ 9.5
Michigan	37.1	− 3.5
California	32.4	− 5.0
Carnegie Inst	30.9	+19.4
Stanford	30.0	+ 4.8
Princeton	28.6	+ 7.5
Smithsonian Inst.	26.0	− 7.3
Illinois	25.0	+16.7
Pennsylvania	24.4	− 4.5
Bur. of Standards	18.9	+ 0.1
Clark	16.0	+ 2.0

If only the number of men is considered, Columbia and Chicago are equal and Harvard has made a larger gain than Chicago within the past four years. But Chicago has increased the number of men in the first hundred by two and in the second hundred by five. When we count up the total scientific strength, we find that Chicago is in advance of Columbia by the equivalent of 15.3 men and has gained more than Harvard by the equivalent of 1.7 men. Wisconsin and Illi-

to mathematical physics, though he might have earned large sums in the time devoted to these. His technical work was doubtless worth far more to society than he was paid for it, but it was worth less than his scientific research. In his three lines of work he was paid inversely as the value of his services.

[13] Cf. SCIENCE, N. S., **24**, p. 707, 1906.

nois also show larger gains than Harvard. While Yale has more scientific men in the thousand than the Johns Hopkins, and Stanford than California, the order of the institutions is in each case reversed when the effective strengths are calculated. The figures on the table appear to be significant and important, and it would be well if they could be brought to the attention of those responsible for the conduct of the institutions to which they relate.

Assuming the validity of the method of weighting used or, at all events, its relative validity for purposes of comparison, considerable reliance may be placed on the figures given in the table. The probable error of a man assigned a weight of one is greater owing to the break at the bottom of the thousand, and this is the largest factor in the probable error of the total. Men just coming within the thousand and men just falling below it are of almost equal merit, yet the former are counted and the latter are not. Still the probable error of a man assigned the weight of one is less than 0.5. When the errors are algebraically added the probable error of the sum increases as the square root of the number, and we may assume the probable errors of the figures given in the table to be not greater than one half of their square root. Thus in the case of Harvard, we may assume that the chances are even that its real strength is between 142 and 152 and its real gain between 14.3 and 18.3.

The scientific strength of an institution does not necessarily measure its total strength. Common observation would lead us to believe that the Johns Hopkins and Cornell are relatively stronger in the natural and exact sciences than Harvard and Yale. We may perhaps assume that the relative strength of a university in different departments tends to be proportional to the number of research degrees conferred. Data concerning these the writer has each year collected and analyzed.[14] Chicago has in the past thirteen years conferred exactly half its doctorates of philosophy in the exact and natural sciences. The percentages for the other universities which confer most of these degrees are: Cornell, 63; Johns Hopkins, 57; Yale and Pennsylvania, 43; Harvard and Columbia, 39. On this basis, the total strength of these universities, the unit as before being a man in the lower part of the thousand scientific men, is:

Harvard	374.4
Columbia	203.2
Chicago	188.2
Yale	140.7
Johns Hopkins	111.1
Cornell	91.9
Pennsylvania	56.7

These figures represent with tolerable accuracy the strength of each institution, so far as the subjects leading to the doctorate of philosophy are concerned. They do not, however, give adequate recognition to the professional schools, schools of law being practically ignored. Harvard has the strongest schools of law and medicine and has a school of theology, so its primacy would not be affected if these were fully accounted for. In its strength Harvard is nearly double Columbia and Chicago, which come close together. Each of these universities has nearly double the strength of the Johns Hopkins, which again has double the strength of Pennsylvania.

The figures at hand enable us to measure the strength of the scientific departments of the different universities. They are given in Table XII. for the ten strongest departments in each of the twelve sciences, together with the gain or loss within the period of four years. The institutions are arranged in the order of strength of the department, but when this is less than four the figures are omitted to avoid giving possible information as to the standing of individuals. The probable errors of the figures given in the table are somewhat less than one half their square root. Thus the strength of the department of mathematics at Chicago is equivalent to 16.8 men on the lower part of the list, and the chances are even that this figure is correct within two places. The

[14] Cf. for the last report Science, N. S., **32**: 231–238, August 19, 1910.

TABLE XII. THE TEN STRONGEST DEPARTMENTS IN EACH SCIENCE TOGETHER WITH THEIR GAIN OR LOSS IN A PERIOD OF ABOUT FOUR YEARS

Mathematics.			Physics.			Chemistry			Astronomy.		
Chicago...	16.8	+2.8	Harvard ...	19.6	+6.1	Mass. Tech.	19	+ 5.9	Chicago....	8.9	+1.9
Harvard...	14.2	+1	Bur. Stand.	15.9	+3.4	Yale	13.6	+ 4.4	California ..	8.7	−1.2
Columbia..	8.4	−1.3	Princeton ..	9.6	+3.9	Dept. Agr. .	12.8	+ 6.5	Harvard ...	7.9	+1.4
Yale.....	8.1	+1.2	Hopkins ...	9.4	+3.2	Harvard ...	11.3	− 2.5	Carnegie ...	6.8	+3.6
Illinois....	8	+8	Chicago....	9.3	+4.1	Hopkins ...	11	+ 3.6	Yale		
Princeton..	6.9	+2.7	Columbia ..	9.1	−8.9	Cornell	8.9	− 0.7	Columbia ..		
Cornell....	6.9	+0.1	Mass. Tech.	9	+2.8	Columbia ..	8.5	+ 1.4	U. S. Navy .		
Wisconsin..	6.7	+6.7	Cornell	8.3	−1.6	Illinois.....	8.3	+ 7 3	Wisconsin ..		
Mass. Tech.	4.1	+1.9	Carnegie ...	8.1	+4.9	Wisconsin ..	8.2	+ 1.8	Penna.		
Stanford...			Dept. Agr. .	6.1	−0.9	Chicago....	8.1	+ 2.4	Michigan...		
Geology.			**Botany.**			**Zoology.**			**Physiology.**		
Geol. Surv.	40.3	−5.3	Harvard ...	18.3	+ 3.2	Harvard ...	22	+3.3	Harvard ...	9.9	+0.1
Yale.....	9.6	+0.4	N. Y. Bot. .	13.5	0	Columbia ..	18.1	+1.4	Yale	7.1	+2.2
Harvard...	7.9	−1.2	Dept. Agr. .	13	−11.6	Chicago ...	13.8	+1.6	Hopkins ...	6.1	−1.1
Chicago...	7.4	−1.3	Chicago....	12.9	+ 2.3	Am.Museum	10.9	−2.6	Rockefeller .	4.9	+2.7
Wisconsin..	6.4	+2.2	Cornell	10	+ 2.8	Cornell	8.8	+2.3	Chicago ...	4.6	+1.4
Smithsonian	5.1	+1.3	Stanford ...	5.9	+ 2.2	Yale	8.3	+2.3	W. Reserve.	4.2	+4.2
Cornell....	4.9	−0.3	Wisconsin ..	5.2	+ 1.1	Stanford ...	7.6	+0.9	California ..	4	+1.8
Hopkins...	4.6	+1.5	Mo. Bot....	5 2	+ 1.4	Dept. Agr. .	7.6	+0.7	Wisconsin ..		
Stanford...			Carnegie ...	5.1	+ 5.1	Smithson...	6.5	−2.4	Cornell		
Columbia..			Hopkins ...			Princeton ..	5.6	+2	New York .		
Anatomy.			**Pathology.**			**Anthropology**			**Psychology.**		
Hopkins...	6.8	− 1.0	Harvard ...	16.5	+4.1	Smithson. ..	10.1	−3.3	Columbia ..	11	+ 1.4
Harvard...	4.9	− 0.3	Hopkins ...	11.5	+1	Columbia ..			Harvard ...	10.2	0
Michigan..			Chicago ...	7	+2	Harvard ...			Clark.....	5.2	+ 0.5
Wistar			Columbia ..	6.2	+0.2	Field Mus. .			Cornell	5	+ 0.5
Wisconsin..			Rockefeller .	6.1	+1.5	California ..			Chicago....	4.4	+ 2.8
Minnesota.			Michigan ..	6	−1.3	Am.Museum			Iowa		
Columbia..			Penna.	4.8	−0.3	Brooklyn...			Wellesley...		
Missouri...			New York..			Clark.....			Wisconsin ..		
Penna.			P. I. Bur.Sci.						Stanford ...		
Chicago...			Wisconsin..						Indiana		

gain in four years has been equivalent to 2.8 such men, and this figure is likely to be correct within 0.8. A gain of this kind may be due to the calling of new men or to the winning of higher places by the same men.

It should be kept in mind that the figures refer only to men included in the first thousand, and that these are graded for distinction in scientific work, ability in teaching and administration being given a subordinate place. A university may conceivably have a department consisting of men of moderate scientific standing, but of personal distinction and superior teaching ability. Some universities even have collegiate professors who are not supposed to permit research work to distract them from teaching and the personal oversight of students. The writer believes that such men belong to the past rather than to the present generation. Under existing conditions scientific men of ability and character will be investigators, and there is a high correlation between these traits and teaching skill. However, this is one of the numerous questions awaiting scientific solution.

Another factor not taken into account by the figures is the age of the men. As a matter of fact, this should not be considered in the present strength of an institution or department, for if a man of forty and a man of sixty have about the same position, they may be regarded as of about equal value for the present. There are drawbacks and advantages of both youth and age which nearly balance each other or regarding which we have at present no exact information. The writer would prefer the merits and faults of the younger men. However this may be, the departments or in-

stitutions having the younger men are in a better position as to the future.

In some cases the strength of the departments should be considered in relation to other factors. Thus, to take an example, the Bussey Institution, the Arnold Arboretum and the Museum of Comparative Zoology are parts of Harvard, whereas the New York Botanical Garden and the American Museum of Natural History are not parts of Columbia, though their heads and other officers may be professors at Columbia, and their facilities may be used for graduate study to the same extent as the Harvard institutes and museums. Or to take another example from the institution with which the writer is connected, the School of Pharmacy has but small educational connection with Columbia, but its professors would be added to the strength of its departments, whereas the Union Theological Seminary, now adjacent to Columbia, is closely affiliated with it educationally, but the professors would not be counted in its strength.

The geologists of the U. S. Geological Survey form the strongest group of men in the same science and under the same institution. The zoologists of Harvard stand next with about half the strength. There then follow in order the physicists of Harvard, the chemists of the Massachusetts Institute, the botanists of Harvard, the zoologists of Columbia, the mathematicians of Chicago, the pathologists of Harvard and the physicists of the Bureau of Standards. These are the departments which have a strength equivalent to fifteen or more men of standing.

Reviewing the sciences in order, it appears that in mathematics Chicago and Harvard are far in the lead, followed by Columbia, Yale and Illinois, the advance of the last institution being noteworthy here and in chemistry. In physics Harvard has double the strength of any other university and has gained largely. Columbia, which four years ago stood first, has lost more than any university in any department. In chemistry, the Massachusetts Institute of Technology stands clearly first, followed by Yale, Harvard and the Johns Hopkins. In astronomy, the great observatories—Yerkes, Lick and Harvard—give their universities precedence. The Mt. Wilson Observatory of the Carnegie Institution has entered this group, while the U. S. Naval Observatory has dropped from it. In geology the U. S. Survey overshadows the universities, among which Yale, Harvard, Chicago and Wisconsin are in the lead. In botany Harvard is far in advance, followed among universities by Chicago and Cornell. The New York Botanical Garden and the Department of Agriculture stand next to Harvard. The Department of Agriculture has, however, suffered severe losses within four years and is now as strong in chemistry as in botany. In zoology Harvard, Columbia and Chicago have by far the strongest departments. The American Museum of Natural History is twice as strong as the U. S. National Museum. In physiology, under which physiological chemistry and pharmacology are included, Harvard is followed by Yale and the Johns Hopkins. In anatomy the Johns Hopkins is followed by Harvard and Michigan. In pathology Harvard is followed by the Johns Hopkins, which precedes Chicago, Columbia and Michigan. The dependencies of the Smithsonian Institution employ nearly half the anthropologists of the country, but they have lost ground in recent years. Columbia, Harvard, California and Clark are the only universities with adequate departments. In psychology Columbia and Harvard have about double the strength of Clark, Cornell and Chicago.

Reviewing the same figures from the point of view of the institutions, the primacy of Harvard among our universities is unchallenged. It stands first in physics, botany, zoology, physiology and pathology; second in mathematics, geology, anatomy, anthropology and psychology, and third in chemistry and astronomy. In every science of the twelve, it is so nearly first that a small change would place it there. This is a remarkable record, and all honor should be given to the men responsible for it. The departments of Chicago and Columbia stand next to Harvard with about half its strength. Chicago stands first in mathematics and astronomy; second

in botany and third in geology, zoology and pathology. Columbia stands first in anthropology and psychology, second in zoology and third in mathematics. The departments at Chicago and Columbia are much more unequally developed than at Harvard. This, however, is not a disadvantage, as with limited resources it is probably desirable for a university to have certain strong departments rather than to have all of equal mediocrity. The departments of mathematics, geology, botany and zoology at Chicago, and of zoology, anthropology and psychology at Columbia are well developed, while in certain other sciences these universities stand at the bottom of the list or even fail to be included among the ten strongest departments. The Johns Hopkins stands first in anatomy, second in pathology and third in physics and in physiology. Yale stands first in geology (which includes mineralogy) and second in chemistry and physiology. The Massachusetts Institute of Technology stands first in chemistry.

The most important recent development of science has been the establishment of endowed institutions for research. The astronomical observatories, often officially but loosely connected with universities, are of earlier origin. Botanical gardens as centers of research also have a long history. There is every argument for similar institutions in each science, either as integral parts of universities, in affiliation with them or as independent institutions; and they are probably being established as rapidly as men can be found to do the work. In all our leading universities there are professors whose attention is devoted to advanced students and investigation, and their laboratories may be regarded as research institutions. Then there are specially endowed foundations, such as the Bussey Institution of Harvard or the new Crocker Cancer Research Fund of Columbia. The Wistar Institute of Biology, affiliated with Pennsylvania, is perhaps the most important institution of its class. Then we have independent institutions endowed for research, of which the most noteworthy are the Smithsonian Institution, the Carnegie Institution of Washington and the Rockefeller Institute for Medical Research. The Smithsonian is of special interest, owing to its early and peculiar foundation, but its endowment is not large according to modern standards, and its energies are mainly taken up in directing government bureaus. It does some publication, but very little research work. The Carnegie Institution with its endowment of $12,000,000 has been a disappointment to those who hoped that it would act the part of a special providence for science and scientific men. It is at present conducting research institutions in various places and publishing the work accomplished. It holds a good position in physics, astronomy, botany and zoology, having in all its departments a total strength of 30.9 men. It has an endowment about equal to the part of the Harvard endowment which may be allotted to the natural and exact sciences, which supports the equivalent of 146 men, who teach as well as carry forward research, so its money, though well spent, does not seem to go so far. A considerable part of the income has, however, been used for construction, equipment and publication. The Rockefeller Institute stands high in pathology and physiology and is continually improving its position. It has been placed under the direct control of scientific men and appears to justify this procedure. The Marine Biological Laboratory at Woods Hole is also conducted by scientific men and although without endowment is an important center for research. The zoologists working there in summer would have a strength greater than any department in any science, including the geologists of the national survey.

Bureaus under the national government stand first in geology and anthropology, second in physics and third in chemistry and botany. Excellent work is accomplished by these and other bureaus, but it is probable that foreign governments which spend far less on science have in their service men of greater distinction. There is a wide-spread belief that the government should only cultivate utilitarian science. In the opinion of the writer this is a mistaken point of view. Applied science can be left to commercial enterprise more

safely than research in pure science. The work which is of value to the whole nation and to the whole world, but has not immediate commercial value to any individual or group, is the kind of work which requires public support. If the man of genius exists he should be given opportunity to use his genius to the best advantage of all. It is extremely difficult to find the men most competent to do research work and to place them under the most favorable conditions, but if the immeasurable importance to society were realized, the difficulties would be solved. It is possible to imagine a national research university to which the ablest men should be drawn, some permanently and some temporarily, there to be given all possible facilities for their work, together with such honorable consideration and such salaries that science and scholarship would attain their due place and be made attractive to the fittest. One can even dream of an international research university to the support of which each nation would contribute a part of the cost of the armaments which it would tend to make useless.

The figures here given show the advantage of statistics over general impressions. The writer is perhaps as well informed as any one in regard to the distribution of scientific men, but some of the figures came as a surprise to him. He knew, or thought he knew, that Harvard had gained and Columbia had lost, but he had no idea of the extent of the change. He supposed that Chicago had lost and that Yale had stood about stationary, whereas both institutions show decided gains. He had no idea that Princeton had among its instructors a larger proportion of scientific men of standing than Columbia, or that the proportion in different universities varied from one half to one sixtieth. And so in many other cases he had wrong impressions, and others probably had wrong impressions of the same or other kinds. We are apt to form general conclusions from striking individual cases without regarding all the conditions. Prominent men lost by or called to an institution attract attention rather than the gradual improvement in the performances of a considerable body of men. The eminent man that an institution loses is not as a rule supplied by a new man, but a large loss in one case is made up by small advances in many cases.

It may be hoped that an exposition of the true conditions will be of service to science. From the point of view of abstract philosophy it may not matter whether a scientific advance is made in Russia or America, at one university or another. But abstract philosophy influences conduct less than concrete loyalties. A man who cares as much for other people's children as for his own is not likely to care greatly for any of them. The president of a leading university has recently urged the importance of increasing salaries, not in order to attract better men to the academic career or to enable them to do better work, but in order that his professors may not be paid less than those of a sister institution. Such a point of view may seem rather naïve, but it is sound human nature and should be appealed to for the improvement of the conditions under which scientific work is done. If the loyalty of alumni could be transferred from football to scholarship, there would result a decided gain to scholarship. The fact that each state wants its university to be as strong as its neighbor's is one of the most potent factors in the advance of the state universities.

Individual conduct is in the main automatic response to chance circumstance. But the organism and the circumstances and especially their interrelations may be altered. Organic life consists of adjustments brought about by the slow processes of nature. We have now reached the extraordinary position from which it is possible to make such adjustments for our own welfare by foresight and scientific method. The individual can prescribe a life of reason more readily than he can follow it. But an environment can be formed in which desirable conduct becomes a reflex response. Reason can have no better use than to select individuals and to arrange circumstances so that science may be advanced and applied for the good of all.

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